ECOLOGICAL ISSUES

UDC 666.171.004.9

ECO-COMPATIBLITY ASSESSMENT OF CONTAINER GLASS PRODUCTION

T. A. Trifonova[1] and N. A. Ishun'kina[1]

Translated from *Steklo i Keramika*, No. 6, pp. 32 – 35, June, 2007.

The life cycle of a container glass enterprise is examined and an assessment of the eco-compatibility of this type of production operation is made. The chief pollutants in atmospheric and work-zone air, discharges of industrial effluent into surface water reservoirs, and process solid wastes are indicated. The chief ecological problems associated with glass production are brought to light and measures for eliminating them are presented.

The Vladimir region is the largest glassware center in Russia. Glass production is the most dynamically growing industry. The container glass sector largely determines this dynamics. The increase in the demand for glassware leads to expansion of production, the introduction of new production capacity, modernization of production lines, and as a consequence intensification of the load on the environment.

To assess the eco-compatibility of the industry it is necessary to analyze the life cycle of the entire enterprise — raw-materials processing and glass production; transporting the raw materials, the finished product, and the wastes; distribution, use, re-use, and recycling of wastes; and, the final disposition of the products and wastes.

As an example, we shall examine the life cycle of a typical container glass enterprise in Vladimir Oblast'.

Characteristics of the enterprise. The basic production plant consists of sectional and machine-tank units (two glass-melting furnaces with average capacity are in operation at the enterprise). Auxiliary production facilities include a machine shop, construction – repair shop, an electric workshop, a boiler house, a compressor house, and a motor transport pool. Virtually all processes in the primary production plant are automated. The enterprise is supplied with natural gas, electricity, compressed air, deep-well water (there are no surface sources of water). The raw materials (sand, soda, dolomite, alumina, chalk, sodium sulfate; selenium and cobalt oxides — clarifying agents — are additional materials) are delivered by truck and railway.

The raw-materials processing and preparation stage includes crushing, drying, pulverizing, sifting, proportioning, and mixing the components of the batch. The crushing and pulverizing are done in hammer crushers and drying is done in drums. At the processing stage large amounts of dust are produced, so that cyclone separators and filters are installed here. Weighed quantities of the prepared raw material are gathered and delivered by conveyers to the mixers, where the material is mixed and moistened. Elevators carry the prepared batch to the production lines.

Glass making occurs at temperatures 1350 – 1400°C in glass-making furnaces which are fueled by natural gas. The batch from the sectional line and cullet (glass brought in from outside the enterprise and waste glass from the enterprise itself) are fed into the furnaces. Feeders feed the ready glass mass, whose temperature and chemical composition are homogenized, into automatic glass-forming machines. Conveyers carry the finished articles into an annealing furnace. After annealing, the container glass is toughened and then shrink wrapped. Large quantities of nitrogen and sulfur wastes are released into the atmosphere during the process of making the glass mass. One of the furnaces is equipped with an economizer, which recovers heat and in the process also catches dust, since solid emission fractions (silica-containing dust) settle on its walls. Oil vapors, acrylaldehyde, and soot are produced during the formation process and removed through an aeration hood.

Cullet arises when glass containers are manufactured. It is re-used as a raw material for making glass.

The scheme of input and output flows was constructed, taking account of the formation of emissions, discharges, and solid wastes, on the basis of our analysis of the life cycle of the primary plant which produces container glass.

[1] Vladimir State University, Vladimir, Russia.

0361-7610/07/0506-0214

The secondary production wastes include the following: ferrous metal scrap; abrasive and emery metal working wastes; used oil; oil-contaminated wiping rags; wastes from the ventilation system in the machine shop; wood scrap, sawdust, and shavings from clean natural wood; paper packing with residues of toxic substances; used tires; used lead batteries; sulfuric battery acid; soil contaminated with petroleum products; fragments of and discarded metal from steel melting electrodes; used mercury discharge lamps; and, other types of wastes.

The following substances produced by the secondary production operations pollute the air in the work zones and in the atmosphere: nitrogen, sulfur, carbon, iron, manganese, nickel, and chromium (VI) oxides; benzopyrene; soot; amorphous boron; suspended substances, silicon-containing, abrasive, metallic, and wood dust; and, nitric, sulfuric, and hydrochloric acids.

Water use and water disposal. The enterprise uses water for moistening the batch, cooling down equipment and the glass mass, as makeup for the in-plant water circulation system, for generating heat in the boiler house, and for housekeeping needs. Water is removed into sewage – household waste plumbing system. Then the waste water is transported to a biological purification treatment plants (BPTPs). No more than 50% of the pollutants are removed, since the BPTP design was only partially implemented. At the present time the enterprise is working to restore and reconstruct the treatment plants to purify the discharged water to a standard level.

A water recycling system is used at the enterprise to conserve fresh water. Petroleum products contaminate water during the formation stages when the glass-mass molds are cooled. Petroleum products are removed in settling tanks. Since the collection of petroleum products is not monitored at this enterprise as it should be and interruptions of water circulation occur often, water objects become contaminated.

The following conclusions can be drawn from our assessment of the life cycle of this glass making enterprise:

the largest quantity of pollutants is produced in the machine – tank lines at the time the glass mass is made (hundreds of tons of nitrogen and sulfur oxides and silicon-containing dust are released into the atmosphere); annealing of the glass articles is also one of the primary sources of air pollution in the work zone and in the atmosphere; a difficult situation unfolds in the sectional lines which remain the main problem of all glass works — large quantities of dust are released when the raw materials are unloaded, prepared, and processed;

most wastes generated during the manufacture of glass containers are class 4 and 5 hazardous (toxic) wastes; the cullet, solid mineral wastes from the sectional line, ferrous metal scrap, lumps from wood working, sawdust, and wood shavings;

the waste water discharged by the enterprise contains large quantities of petroleum products.

The eco-performance was assessed taking account of the eco-compatibility factor. The assessment is based on an analysis of the materials balance:

$$M_1 + M_2 = M_3 + M_4,$$

where M_1 is the primary raw material used in production, tons/year; M_2 is the secondary raw and other materials; M_3 is the finished product, tons/year; $M_4\,(m_4)$ is the total production of wastes, tons/year (r.t.m./kg):

$$M_4\,(m_4) = M'_4\,(m'_4) + M''_4\,(m''_4),$$

where $M'_4\,(m'_4)$ are the wastes from structural placement; $M''_4\,(m''_4)$ are the emissions and discharges, including at the level equal to the maximum admissible emissions and discharges (MAE and MAD).

For assessment purposes, the wastes, emissions, and discharges are expressed in units of the relative toxic mass, r.t.m./kg pollutant;

$$m = \sum_{i=1}^{n} l_{\mathrm{r}i} M_i,$$

where i is the amount of pollutant; $l_{\mathrm{r}i}$ is the relative toxicity index which is

$$l_{\mathrm{r}i} = 1/\mathrm{MAC}_{\mathrm{fw}i};$$

for discharges into water objects and

$$l_{\mathrm{r}i} = 0.01/\mathrm{MAC}_{\mathrm{mot}i},$$

for air and soils, where $\mathrm{MAC}_{\mathrm{fw}i}$ is the maximum admissible concentration of a toxic substance in fishery waters and $\mathrm{MAC}_{\mathrm{mot}i}$ is the maximum admissible concentration of a toxic substance for maximum one-time exposure [1].

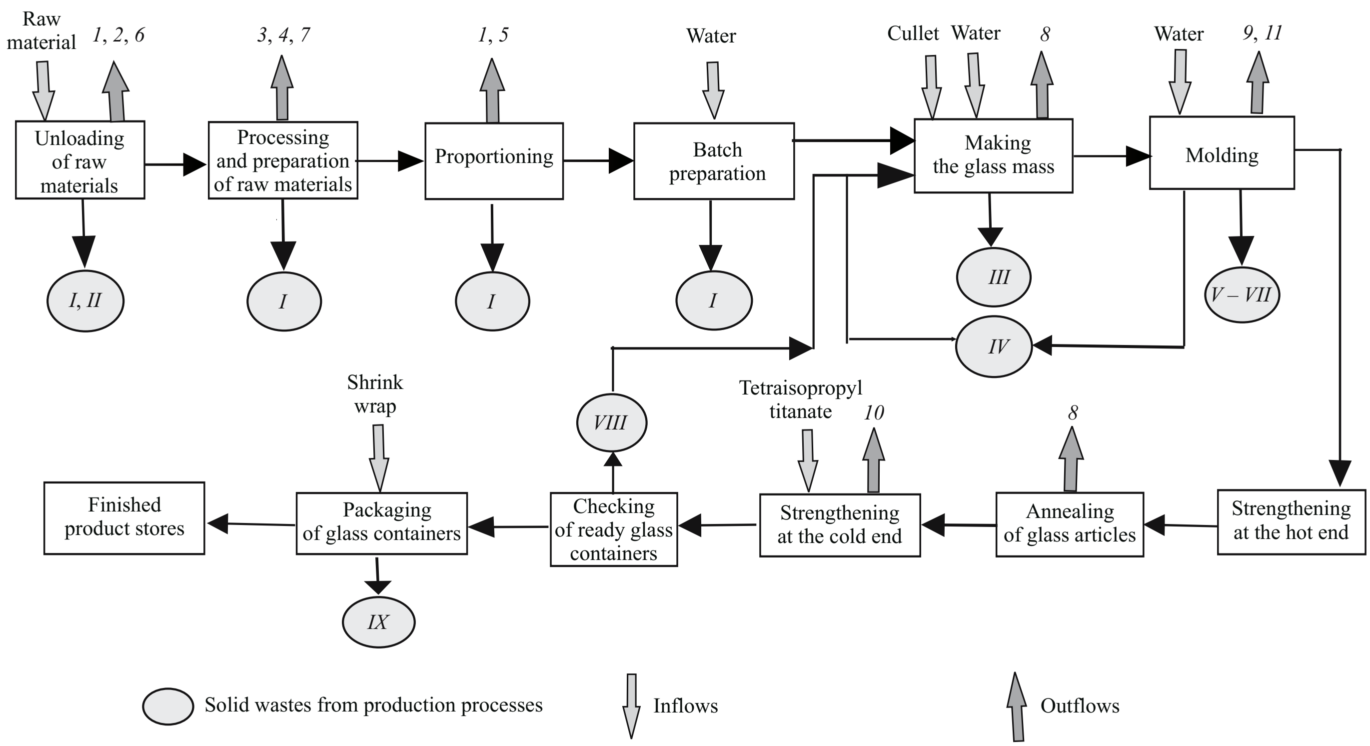
The complete eco-compatibility factor C (eco-performance) is given by the expression

$$\mathrm{C} = \eta \mathrm{P} M,$$

where η is the effectiveness of the systems regulating the impact on the environment; $\eta = m'_4/m_4 = (m_4 - m''_4)/m_4$; P is the eco-compatibility factor of structures; $\sum m''_{4\mathrm{MAE\,(MAD)}} / m''_4$ ($m''_{4\mathrm{MAE\,(MAD)}}$ is the emission (discharge) of pollutants at the MAE (MAD) level); and, $M = M_3/(M_1 + M_2)$ is the process yield of the primary product, tons/year; for the enterprise considered here $M = 0.741$ tons/year.

Contamination of atmospheric air. This enterprise discharges into the environment more than 1000 t of various substances, most of which are nitrogen, sulfur, and carbon oxides and inorganic dust containing up to 20% SiO_2 (Table 1). The enterprise has more than 30 organized and unorganized sources of emissions, the primary ones being the stacks of the glass-making furnaces.

Contamination of water objects. Twenty named contaminants are discharged into a surface reservoir. The MAD is ex-



Scheme of inflows and outflows for a container glass plant (main production operations): *solid wastes from production processes*: *I*) raw materials wastes; *II*) packaging materials with residues of toxic substances; *III*) refractory scrap; *IV*) erclase (cullet from cleaning congealed glass melt); *V*) oil-contaminated wiping rags; *VI*) used oils; *VII*) petroleum products; *VIII*) recycled cullet; *IX*) film materials; *outflows*: *1*) sodium carbonate; *2*) aluminum oxide; *3*) sodium sulfate; *4*, *5*, and *6*) inorganic dust: > 70% SiO_2, 70 – 20% SiO_2, and < 20% SiO_2, respectively; *7*) NO_2, SO_2, and CO_2; *8*) nitrogen and sulfur oxides, inorganic dust (< 20% SiO_2); *9*) suspended matter, soot, acrylaldehyde, mineral oil; *10*) isopropyl alcohol; *11*) water effluent contaminated with petroleum products.

ceeded with respect to all indicators. We took account of the main pollutants to calculate the ecological impact (Table 2).

Handling wastes. More than 500 tons solid wastes/year are produced at this enterprise. Most of them are class 4 and 5 hazardous wastes. Some of the process wastes are used at the enterprise, and the remaining wastes are reprocessed or sent to a dump (Table 3).

The conventional mass of the of the solid wastes (for this enterprise m'_4 = 380,092 r.t.m./kg) is calculated similarly to the conventional mass of the emissions and discharges.

The total production of pollutants is

$$m_4 = 41{,}769.50 + 1130.78 + 380{,}092.00 = 422{,}992.28 \text{ r.t.m./kg}.$$

The coefficients are determined as follows from the quantities obtained:

$$\eta = 380{,}092.00 \text{ r.t.m./kg} / 422{,}992.28 \text{ r.t.m./kg} = 0.899;$$

$$P = (119.89 \text{ r.t.m./kg} + 8928.0 \text{ r.t.m./kg}) / (1130.78 \text{ r.t.m./kg} + 41{,}769.5 \text{ r.t.m./kg}) = 0.211.$$

TABLE 1.

Pollutant	Actual emission, tons/year	Maximum allowable emission, tons/year
Nitrogen dioxide	94.229	22.9
Oxides:		
nitrogen	671.717	107.6
sulfur	334.004	134.5
Inorganic dust (up to 20% SiO_2)	349.425	40.7
Total	1449.375	305.7
In r.t.m./kg	41769.500	8928.0

TABLE 2.

Pollutant	Timed discharge, tons/year	Maximum admissible discharge, tons/year
Suspended matter	1.673	0.110
Chlorides	1.833	0.548
Sulfates	2.743	0.730
Nitrate ions	0.415	0.066
Petroleum products	0.015	0.002
Total	6.679	1.456
In r.t.m./kg	1130.780	119.890

TABLE 3.

Wastes	Waste amounts, % total mass	Toxicity class	Handling wastes
Used mercury lamps	0.40	1	Sent to a special reprocessing plant
Used oils	1.17	3	Used at the enterprise to lubricate molds
Other petroleum product wastes	0.52	3	Sent to a special reprocessing plant
Oil-contaminated wiping rags (oil content 15% or higher)	0.20	3	Used for firing during construction – repair work
Battery sulfuric acid	0.09	2	Neutralized at the enterprise
Used lead batteries	0.22	3	Sent to a special reprocessing plant
Ferrous metal scrap (unsorted)	27.03	5	Same
Sawdust and shavings from natural clean wood	12.22	5	Given to the public for household use
Scrap from natural clean wood	19.56	5	Same
Polyethylene film scraps	0.18	5	Sent to a special reprocessing plant
Dust (or powder) from grinding ferrous metals with metal content 50% or more	0.76	4	Same
Raw materials wastes	13.14	4	Re-used as raw material
Residue on the ventilation systems in the sectional line	0.78	4	Used for repairing roads
Cullet	11.20	5	Returned into the production process
Chamotte brick scrap	0.38	5	Re-used
Solid housekeeping wastes	11.76	5	Removed to dump for solid household wastes

Therefore the eco-compatibility factor is

$$C = 0.211 \times 0.899 \times 0.741 = 0.14.$$

The value obtained for the complete eco-compatibility factor (eco-performance) of technological processes and practices is very small. This shows that ecological problems exist at all stages of production. Large quantities of raw pollutants are flowing into the environment. The manufacturer must increase the eco-compatibility factor of the treatment plants. This can be done by upgrading the existing equipment — using more efficient facilities for cleaning discharges and emissions — and by improving working conditions and increasing the proficiency of the service workers.

On the basis of our analysis of the production life cycle, calculations of the eco-compatibility factor, and data from the annual reports of the Administration of Vladimir Oblast' on the state of the environment, it becomes obvious that glass container manufacturing, just like any sector of industry, has an appreciable effect on the environment and the health of the general population (directly on the workers in glass enterprises).

The primary reasons for the unsatisfactory ecological conditions at these enterprises are deterioration of the process equipment and treatment facilities and the fact that technical characteristics of the equipment used at the enterprise do not meet the design criteria. Most glass factories operate old structures which no longer meet the ecological requirements. The primary problem is that modern process and treatment facilities are expensive. However, this price is not comparable to the harm done to the environment and public health. In any case, even the largest economic outlays prove to be worthwhile.

The position of some glass enterprises could be exacerbated by departing from the norms provided in the design solutions. Measures for protecting the environment and efficient use and replacement of natural resources are developed, the parameters determining the effect of an object on elements in the environment are determined, and forecasts of the ecological and social consequences of building and operating objects are formulated at the stages of ecological analysis by experts. All decision making is coordinated with government agencies which strictly monitor each step of the analysis performed by experts. If such monitoring is done continually (during the entire period of resource management), then there will be no incompatibility between the situation at the enterprise and the design solutions. Strict monitoring is possible only when knowledgeable managing practices are used and ecologically trained service workers and management are present at the enterprise.

The adoption of a system for controlling the environment at an enterprise is the most effective solution to the existing ecological problems of the glass industry. A detailed analysis of each technological operation, elimination of bottlenecks and negative aspects by choosing the best solution, assessment of the measures adopted, and striving to improve production practices are the necessary ingredients for creating the conditions required to increase eco-compatibility of the glass container industry.

Public and government agencies must exercise strict monitoring of the operations of an enterprise, and the enterprise itself must provide reliable, timely, complete, and accessible ecological information.

REFERENCES

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